OFFICE OF INDUSTRIAL TECHNOLOGIES

	FY 1995
Office of Industrial Technologies - Grand Total	$31,142,477
Office of Waste Reduction Technologies	$ 825,000
Waste Material Management Division	$ 825,000
Solar Materials Research	$ 825,000
Materials Preparation, Synthesis, Deposition, Growth or Forming	$ 825,000
Photocatalysts Based on Titanium Dioxide	300,000
Solar Materials Processing	525,000
Office of Industrial Processes	$30,317,477
Advanced Industrial Materials Program	$8,932,000
Materials Preparation, Synthesis, Deposition, Growth or Forming	$4,539,000
Synthesis and Design of $MoSi_2$ Intermetallic Materials	785,000
Development of Weldable, Corrosion Resistant Iron Aluminide Alloys	250,000
Composites and Coatings Through Reactive Metal Infiltration	478,000
Magnetic Field Processing of Inorganic Polymers	190,000
Development of New Composite Aerogel Materials	100,000
Microwave Processing of Continuous Ceramic Oxide Filaments	368,000
Conducting Polymers: Synthesis and Industrial Applications	316,000
Microwave Assisted Chemical Vapor Infiltration	210,000
Chemical Vapor Deposition Ceramic Synthesis	400,000
Gel Casting Technology	155,000
Uniform Droplet Spray Forming	470,000
Biomimetic Thin Film Synthesis	325,000
Chemical Recycling of Plastics	300,000
Composites and Blends from Biobased Materials	192,000
Materials Properties, Behavior, Characterization or Testing	$1,075,000
Characterization of Three-Way Automotive Catalysts	300,000
Composite Tubes - Materials for Recovery Boilers	775,000
Materials Structure and Composition	$1,518,000
Metallic and Intermetallic Bonded Ceramic Composites	330,000
Advanced Ordered Intermetallic Alloy Development	475,000
Rapid Solidification Processing of Metal Alloys	192,000
Processing of Polymers in a Magnetic Field	316,000
Microwave Joining of SiC	205,000

OFFICE OF INDUSTRIAL TECHNOLOGIES (Continued)

	FY 1995
Office of Industrial Processes (continued)	
Advanced Industrial Materials Program (continued)	
Device or Component Fabrication, Behavior or Testing	$ 1,800,000
Ni_3Al Technology Transfer - Steel Mill Rolls and Furnace Fixtures	1,050,000
Advanced Microwave Processing Concepts	250,000
Selective Inorganic Thin Films	400,000
Chemical Vapor Infiltration of TiB_2 Composites	100,000
Advanced Turbine Systems Program	$11,000,000
Device or Component Fabrication, Behavior or Testing	$11,000,000
Ceramic Components for Stationary Gas Turbines in Cogeneration Service	6,500,000
Long-Term Testing of Ceramic Components for Stationary Gas Turbines	500,000
ATS Materials Base Technology Support	4,000,000
Heat Exchanger Program	$ 2,108,477
Materials Properties, Behavior, Characterization or Testing	$ 617,000
Advanced Heat Exchanger Material Technology Development	617,000
Device or Component Fabrication, Behavior or Testing	$ 1,491,477
Ceramic Composite Heat Exchanger for the Chemical Industry	138,801
HiPHES System for Energy Production	316,676
HiPHES System for Ethylene Production	1,036,000
Continuous Fiber Ceramic Composites (CFCC) Program	$8,277,000
Materials Preparation, Synthesis, Deposition, Growth or Forming	$5,977,000
CFCC Program - Industry Tasks	5,977,000
Materials Properties, Behavior, Characterization or Testing	$2,300,000
Continuous Fiber Ceramic Composites (CFCC) Supporting Technologies	2,300,000

OFFICE OF INDUSTRIAL TECHNOLOGIES

Through the Industries of the Future strategy, the DOE Office of Industrial Technologies (DOE-OIT) is stimulating the development and use of industrial technologies that increase energy efficiency and lower the costs of environmental protection and regulatory compliance. The Industries of the Future strategy is concentrating on seven industries-petroleum refining, chemicals, pulp and paper, steel, aluminum, foundries and glass-which are vital to the U.S. economy; and which at the same time, account for 88 percent of energy consumed in manufacturing and more than 90 percent of the wastes generated. Research in support of the Industries of the Future is being conducted in partnership with industry, according to R&D priorities established by industry participants. Materials research addresses the need for industrial processes to run at increased temperatures with longer service lives, reduced downtime, and lower capital costs.

OFFICE OF WASTE REDUCTION TECHNOLOGIES

WASTE MATERIAL MANAGEMENT DIVISION

SOLAR MATERIALS RESEARCH

The objective of solar materials research is to identify and develop viable materials processes that take advantage of the attributes of highly concentrated solar fluxes. Concentrated sunlight from solar furnaces can generate temperatures well over 2000 °C. Thin layers of the illuminated surfaces can be driven to very high temperatures in fractions of a second. Concentrated solar energy can be delivered over very large areas, allowing for rapid processing. The result is more efficient use of bulk materials and energy, potentially lower processing costs, and reduced need for strategic materials, all with a technology that does not damage the environment. Also being developed are catalysts for processes that use the sun's energy to destroy hazardous organic chemicals.

MATERIALS PREPARATION, SYNTHESIS, DEPOSITION, GROWTH OR FORMING

6. **PHOTOCATALYSTS BASED ON TITANIUM DIOXIDE**
   $300,000
   DOE Contact: Frank Wilkins, (202) 586-1684
   NREL Contact: Daniel M. Blake, (303) 275-3702

The objectives of this work are to develop materials that are more active photocatalysts for the oxidation of organic compounds in air or aqueous phases, determine the characteristics of titanium dioxide and modified forms that influence the activity, and test the catalysts in laboratory and pilot scale reaction systems. Potential catalysts are prepared inhouse, by NREL subcontractors, or obtained from commercial sources. The ultimate goal is to make photocatalytic oxidation processes for removal of hazardous organic compounds from contaminated air and water a cost-effective treatment option for environmental remediation and process emission control.

Keywords: Photocatalyst, Titanium Dioxide, Oxidation, Remediation

7. **SOLAR MATERIALS PROCESSING**
   $525,000
   DOE Contact: Frank Wilkins, (202) 586-1684
   NREL Contact: Allan Lewandowski, (303) 384-7470

The objective of this work is to develop an alternative method of processing various advanced materials using concentrated sunlight as the energy source. A number of processes have been explored including metalorganic deposition of thin films on ceramics, synthesis, production and processing of advanced ceramic powders, solar assisted chemical vapor deposition of thin films on various substrates, rapid thermal heat treating and cladding, solar production of Fullerenes, and other surface modification techniques. The project seeks to explore a wide range of technologies, assess those with commercial potential and develop the most promising technologies in conjunction with industry. Several technologies have demonstrated significant technical success and are now being explored more fully through Cooperative Research and Development Agreements.

Keywords: Solar Processing, Advanced Materials, Ceramics, Metallization, Fullerenes, Cladding, Concentrated Sunlight, Solar Furnaces

OFFICE OF INDUSTRIAL PROCESSES

ADVANCED INDUSTRIAL MATERIALS PROGRAM

New or improved materials can save significant energy and improve productivity by enabling systems to operate at higher temperatures, last longer, and reduce capital costs. The emphasis of the Advanced Industrial Materials program is on industrial needs identified for the seven OIT industries of the Future. Efforts in 1995 were focused on forging partnerships between industry and the National

Laboratories for commercialization of new materials and processes. The program manager is Charles A. Sorrell, (202) 586-1514.

MATERIALS PREPARATION, SYNTHESIS, DEPOSITION, GROWTH OR FORMING

8. **SYNTHESIS AND DESIGN OF $MoSi_2$ INTERMETALLIC MATERIALS**
   $785,000
   DOE Contact: Charles A. Sorrell, (202) 586-1514
   Los Alamos National Laboratory Contacts:
   J. J. Petrovic, (505) 667-0125 and Richard Castro, (505) 667-5191

The objective of this project is to develop $MoSi_2$-based composites that will combine good room temperature fracture toughness with excellent oxidation resistance and high-temperature strength for industrial applications. Processing methods such as spray forming and electrophoretic deposition are being investigated also. Focus has been on development and characterization of $MoSi_2$-SiC, $MoSi_2$-Si_3N_4 and $MoSi_2$-Al_2O_3 composites; as well as on plasma sprayed $MoSi_2$ materials and microlaminate composites. Current emphasis is on the fabrication of prototype $MoSi_2$ industrial components (e.g., fuel burners, gas injection tubes, furnace heating elements, and metal processing equipment) and, in particular, $MoSi_2$ components for fiber glass processing. The project has a number of research collaborations in place with industrial partners.

Keywords: Composites, Intermetallics, Molydisilicides

9. **DEVELOPMENT OF WELDABLE, CORROSION RESISTANT IRON ALUMINIDE ALLOYS**
   $250,000
   DOE Contact: Charles A. Sorrell, (202) 586-1514
   ORNL Contact: P. J. Maziasz, (615) 574-5082

Iron-aluminides show excellent corrosion/oxidation resistance to at least 1100°C. Alloying has been shown to considerably improve room-temperature ductility and high-temperature tensile and creep strength relative to binary alloy systems. The objectives of this project are to complete alloy development efforts to maximize weldability and properties improvements in FeAl alloys for structural applications, and to develop the potential for weldable FeAl alloys for use in weld-overlay cladding applications. The initial alloy development phase to improve the weldability and mechanical properties of these alloys was completed in FY 1994. The optimum FeAl base alloy for weldability, fabricability and mechanical properties was found to be an Fe-36Al-0.2Mo-0.05Zr-0.13C (at%) alloy; an FeAl alloy with significantly better weldability and high temperature strength. Improved resistance to hydrogen effects at room-temperature is obtained with a boron micro-alloyed modification of the base alloy. In FY 1995 this project entered the fabrication technology phase, to produce components for industry testing. Two parallel paths are being pursued. One is to develop coatings and cladding of FeAl on conventional structural steels and alloys being used in industrial applications today. These should enable immediate testing of FeAl for its oxidation/corrosion/wear resistance in demanding industrial environments of interest. The other is to fabricate monolithic FeAl components and hardware for industrial testing.

Keywords: Iron Aluminides, Coatings, Claddings, Thermophysical Properties

10. **COMPOSITES AND COATINGS THROUGH REACTIVE METAL INFILTRATION**
    $478,000
    DOE Contact: Charles A. Sorrell, (202) 586-1514
    Sandia National Laboratories Contact:
    R. E. Loehman, (505) 844-2222

Ceramic-metal composites have advantages as engineering materials because of their high stiffness-to-weight ratios, good fracture toughness, and because their electrical and thermal properties can be varied through control of their composition and microstructure. However, broader commercial application of these materials requires improvements in synthesis and processing so that high-performance parts can be produced more economically. Reactive metal infiltration is a promising new route to synthesize and process a wide range of ceramic and metal-matrix composites to near-net-shape with control of both composition and microstructure. Efforts have focused on determining the kinetics of infiltration of Al into dense mullite as well as identifying other metal-ceramic systems for potential reactive metal infiltration processing. Measured properties of composites have shown significantly improved toughness with little loss in stiffness compared with the ceramic preform.

Keywords: Metal Matrix Composites, Reactive Metal Infiltration, Ceramics

11. **MAGNETIC FIELD PROCESSING OF INORGANIC POLYMERS**
    $190,000
    DOE Contact: Charles A. Sorrell, (202) 586-1514
    Idaho National Engineering Laboratory Contact:
    D. C. Kunerth, (208) 526-0103

The application of magnetic fields during processing has been shown to modify the physical and chemical properties of inorganic polymers. The objective of this project is to develop the technical basis for improving the physical properties of inorganic polymers using electromagnetic fields. Current efforts focus on developing a basic understanding of magnetic field processing of polyphosphazene materials to be utilized as chemical separation membranes. The physical and chemical properties of the polyphosphazene polymers have been modified using magnetic fields. Results show that membrane morphologies and transport properties change with the application of magnetic fields; providing a small amount of molecular texturing. In addition, processing techniques as simple as DC magnetic fields developed by permanent magnets or microwave fields can be used.

Keywords: Polymers, Magnetic Field Processing

12. **DEVELOPMENT OF NEW COMPOSITE AEROGEL MATERIALS**
    $100,000
    DOE Contact: Charles A. Sorrell, (202) 586-1514
    Lawrence Berkeley Laboratory Contact:
    A. Hunt, (415) 486-5370

Aerogel materials are porous, low density, nanostructured solids with many unique properties including very low thermal conductivity, transparency, high surface area, and low sound velocity. The objective of this project is to develop new aerogel-based composites materials through sol-gel chemistry, supercritical drying, and chemical vapor infiltration. An infrared opacified silica aerogel was produced using chemical vapor infiltration methods that displayed improved thermal and physical properties. This provides higher temperature and stronger aerogel thermal insulation. The process was generalized to produce a wide variety of new composite materials. Some of these composites displayed unusual characteristics (e.g., photo-luminescence in silicon silica composites) due to quantum confinement effects.

Keywords: Thermal Insulation, Sol-Gel, Aerogels

13. **MICROWAVE PROCESSING OF CONTINUOUS CERAMIC OXIDE FILAMENTS**
    $368,000
    DOE Contact: Charles A. Sorrell, (202) 586-1514
    Los Alamos National Laboratory Contacts:
    G. J. Vogt, (505) 665-4988 and J. D. Katz, (505) 665-1424

The objective of this research is to develop economic microwave processing technology for the complete manufacturing of continuous ceramic oxide filament tows from extruded solution-based gels with greater energy efficiency than conventional thermal processing. The approach is to use volumetric microwave absorption to heat ceramic oxide tows in order to drive the process drying, prefiring, and sintering in the preparation of continuous tows from solution-based gels. Microwave heating of filament tows was successfully controlled by pulse modulation of a magnetron source and by active feedback control of the pulse rate and frequency through an optical feedback sensor. Current efforts are focused on developing microwave techniques for drying, organic burnout, and sintering of sol-gel filament tows. The energy efficiency and economics of microwave processing will be directly compared to those of conventional thermal processing.

Keywords: Microwave Processing, Filaments

14. **CONDUCTING POLYMERS: SYNTHESIS AND INDUSTRIAL APPLICATIONS**
    $316,000
    DOE Contact: Charles A. Sorrell, (202) 586-1514
    Los Alamos National Laboratory Contact:
    S. Gottesfeld, (505) 667-0853

The process of separating pure components out of a mixture of gases is of great industrial importance. Current gas separation technologies have major shortcomings, including poor energy efficiency and the generation of secondary pollution. The objective of this project is to develop superior membranes for gas separation using doped polyaniline polymers.Because these materials are electrical conductors, membrane properties can be changed following synthesis, and even during use, to control the process flow. A key portion of this project is fabrication of integrally skinned, asymmetric membranes of polyaniline using highly refined solution chemistry. The resultant membranes, consisting of a dense very thin "skin" (1 mm thick, or less) on top of a porous (e.g., 40 mm thick) base layer, should enable a dramatic increase in gas permeability while maintaining the high selectivity by the dense "skin."

Keywords: Electrically Conducting Polymers, Gas Separation, Capacitors

15. **MICROWAVE ASSISTED CHEMICAL VAPOR INFILTRATION**
    $210,000
    DOE Contact: Charles A. Sorrell, (202) 586-1514
    Los Alamos National Laboratory:
    D. J. Devlin, (505) 667-9914

The use of microwave heating of ceramic fiber preforms is being explored as a means of developing an improved rapid process for the fabrication of composites by chemical vapor infiltration. The volumetric and preferential heating of certain materials by microwaves provides a means of establishing inverted thermal gradients in a preform. The result is the ability to rapidly infiltrate the preform developing the matrix from the inside-out. A successful microwave/RF assisted infiltration process would eliminate may limitations encountered in conventional approaches. Work has been initiated with an industrial partner to further develop a microwave driven densification process for the manufacture of carbon-carbon composites. Research with another industrial partner is being conducted to develop membranes with controlled porosity for the separation of oleofins from hydrogen streams.The development of the required pore structure entails the closing of the pores of a suitable substrate by vapor deposition techniques.

Keywords: Microwave Processing, Chemical Vapor Infiltration, Ceramics, Composites

16. **CHEMICAL VAPOR DEPOSITION CERAMIC SYNTHESIS**
    $400,000
    DOE Contact: Charles A. Sorrell, (202) 586-1514
    Sandia National Laboratories - Livermore Contact:
    M. D. Allendorf, (415) 294-2895

Comprehensive models, including detailed gas-phase and surface chemistry coupled with reactor fluid mechanics, are required to optimize and scale-up chemical vapor deposition (CVD) processes. The objective of this project is to use the unique diagnostic and modeling capabilities at the Sandia National Laboratory - Livermore to understand and develop new techniques for chemical vapor deposition (CVD). A research reactor, originally constructed with DOE-OIT funding, is being used to determine identities and amounts of gaseous phase species present during CVD. Research efforts are focused on development of CVD processes for oxide fiber-preforms and plate glass surfaces for the improvement of properties.

Keywords: Chemical Vapor Deposition, Gas-Phase Chemistry, Modeling

17. **GEL CASTING TECHNOLOGY**
    $155,000
    DOE Contact: Charles A. Sorrell, (202) 586-1514
    ORNL Contact: M. A. Janney, (615) 576-5183

The sol-gel process is being adapted to production of aluminum oxide tubes for use in high-intensity industrial lighting. The sol-gel process will produce identical materials at lower temperatures and in far less time than do conventional methods which involve prolonged high temperature sintering with sintering aids. The process also allows for fabrication of large and complex shapes. Tubes which meet lighting specifications for crystallinity and transparency have been fabricated in a variety of sizes and shapes at Oak Ridge National Laboratory.

Keywords: Sol-Gel, Aluminum Oxide, Lighting Tubes

18. **UNIFORM DROPLET SPRAY FORMING**
    $470,000
    DOE: Contact: Charles A. Sorrell, (202) 586-1514
    ORNL Contact: Vinod Sikka, (615) 574-5123

A method for producing very uniform, spherical droplets of molten metal, with controllable diameters between micron and millimeter size was developed by faculty at the Massachusetts Institute of Technology and Tufts University and applied to low melting point metals. The purpose of this project is to adapt the process to higher melting materials, e.g., intermetallic alloys, stainless, steel, superalloys; to provide superior metal powders for the powder metallurgy industry and to develop methods for spray coating or casting of high temperature materials, such as aluminide intermetallics. Participants in the research include Massachusetts Institute of Technology, Tufts University and powder metal companies. The process has been scaled up for production of droplets of high melting alloys. Spray forming of metallic systems is being investigated. Production of new alloys and laminar materials will be explored in the future.

Keywords: Spray Forming, Spray Casting

19. **BIOMIMETIC THIN FILM SYNTHESIS**
    $325,000
    DOE Contact: Charles A. Sorrell, (202) 586-1514
    Pacific Northwest National Laboratory Contact:
    G. L. Graff, (509) 375-6786

The objective of this project is to adapt the features of mineralization processes used by bioorganisms to the development of materials with improved properties over conventionally processed materials and demonstrate industrial relevance of biomimetics thin film processing for industrial coatings. Calcium phosphate films have been deposited on Ti metal bone implants coated with self-assembled monolayers. Use of solution techniques to develop oriented, fully dense films of magnetite has been successful. Solution complexation methods have been used to grow thick tin oxide coatings on plastics under mild pH conditions. Impermeable high density polyethylene (HDPE)/Al/HDPE sandwich composite has been produced using cup drawing techniques. Future efforts will explore the potential for biomimetic processingin biomedical applications and in high-valueadded products or industries such as microelectronics where the patterning advantage of biomimetics can be exploited.

Keywords: Biomimetic, Organic Interfaces, Ceramic Coatings

20. **CHEMICAL RECYCLING OF PLASTICS**
$300,000
DOE Contact: Charles A. Sorrell, (202) 586-1514
National Renewable Energy Laboratory Contact:
R. J. Evans, (303) 231-1384

The goal of this project is to identify conditions for the production of high-value chemicals from mixtures of waste plastics by the use of selective pyrolysis. Sorting the feed and purifying the products are minimized by controlling reaction conditions so that target products can be collected in high yields. Control is achieved by taking advantage of differences in reaction rates, catalysis, and co-reactants. Target waste streams are post-consumer wastes that can range from commodity plastics to high-value engineering blends. Efforts are focused on increasing the yield and purity of the monomer, caprolactam, from nylon 6 carpet. In other applications, the conversion of poly(ethylene terephthalate) (PET) to its monomer, dimethyl terephthalate has expanded from mixed plastic bottle wastes to polyester fiber textile blends. Also, the intelligent chemical processing system has demonstrated quantitative and qualitative ability to analyze carpet mixtures.

Keywords: Plastics Recycling, Pyrolysis, Waste Streams

21. **COMPOSITES AND BLENDS FROM BIOBASED MATERIALS**
$192,000
DOE Contact: Charles A. Sorrell, (202) 586-1514
National Renewable Energy Laboratory Contacts:
S. S. Kelley and S. S. Shojaie, (303) 384-6123

The program is focused on the development of composites and blends from biobased materials for use as membranes, high-value plastics, and lightweight composites. Biobased materials include novel cellulose derivatives, wood modified with synthetic monomers, and wood fiber/synthetic plastic composites. Research efforts have focused on two areas: (1) composites and blends from cellulose derivatives, and (2) wood reinforced with synthetic monomers. The program is designed to evaluate the thermal, mechanical, and permeselective properties of these materials and relate their performance to the chemical structure and morphology of the composites or blends. Current efforts are focused on utilizing cellulose esters to prepare novel composites and blends. These materials have improved permeselective and/or compaction properties relative to unmodified cellulose esters.

Keywords: Biobased Materials, Composites, Thermomechanical Testing

MATERIALS PROPERTIES, BEHAVIOR, CHARACTERIZATION OR TESTING

22. **CHARACTERIZATION OF THREE-WAY AUTOMOTIVE CATALYSTS**
$300,000
DOE Contact: Charles A. Sorrell, (202) 586-1514
ORNL Contact: E. A. Kenik, (615) 574-5066
General Motors-AC Rochester Division Contact:
W. LaBarge, (313) 257-0875

Platinum-rhodium based three-way-catalysts (TWC) currently meet the required emissions standards; however, higher than optimum Pt-Rh loadings are often required to meet lifetime requirements. Understanding the changes of the TWC conversion efficiency with aging is a critical need in improving the catalysts. The objective of this project is to critically evaluate catalytic materials in as-produced and aged conditions and correlate materials and systems development to improve catalyst performance and lifetime while decreasing emissions. Current efforts focus on characterizing the microstructural and chemical state of both noble metals and substrates in as-produced catalyst materials with a wide range of spectroscopy and analysis techniques.

Keywords: Automotive Catalysts, Surface Analytical Analysis, Light and Electron Optical Analysis

23. **COMPOSITE TUBES - MATERIALS FOR RECOVERY BOILERS**
$775,000
DOE Contact: Charles A. Sorrell, (202) 586-1514
ORNL Contact: James R. Kaiser, (615) 574-4453

The purpose of this project is to determine the cause of failure of composite tubes used in Kraft Black Liquor recovery boilers during pulp and paper making, and to develop new materials to eliminate failures. The project consists of three efforts: (1) to obtain operating data and failure analyses from pulp and paper companies, boiler manufacturers and composite tube manufacturers, (2) determination of residual stresses in new and used composite tubes and microstructural characteristics of tubes as related to stresses and failure mechanisms, and (3) development of new materials and/or fabrication methods for improvements in boiler efficiency, service life, and safety. Participants include Oak Ridge National

Laboratory, Institute of Paper Science and Technology, and 11 industrial collaborators.

Keywords: Recovery Boilers, Composite Tubes, Paper

MATERIALS STRUCTURE AND COMPOSITION

24. **METALLIC AND INTERMETALLIC BONDED CERAMIC COMPOSITES**
 $330,000
 DOE Contact: Charles A. Sorrell, (202) 586-1514
 ORNL Contacts: T. N. Tiegs and K. B. Alexander, (615) 574-0631
 Lawrence Berkeley Laboratory Contact: R. O. Ritchie, (415) 642-0417

To improve the reliability of ceramic components, new approaches to increasing the fracture toughness of ceramics over an extended temperature range are needed. One method is the incorporation of ductile phases into ceramic matrix alloys for local plastic deformation during crack bridging processes. This deformation acts to dissipate the strain energy introduced by the applied stress, thus increasing the fracture toughness of the composite. This objective of this program is to develop ceramic composites with high fracture toughness for intermediate temperature use in wear, tribological and engine applications. Results have shown that nickel aluminide additions have been shown to be an effective toughening agent in ceramic matrices if the microstructural distribution is carefully controlled. The microstructural features yielding optimal toughening have been identified and composites have been fabricated with properties comparable to, or better than, commercial ceramic composites at a lower raw material cost.

Keywords: Ceramics, Composites, Nickel Aluminide

25. **ADVANCED ORDERED INTERMETALLIC ALLOY DEVELOPMENT**
 $475,000
 DOE Contact: Charles A. Sorrell, (202) 586-1514
 ORNL Contact: C. T. Liu, (615) 574-4459

Many ordered intermetallics possess unique properties and have the potential to be developed as new materials for energy related applications. The objective of this project is to develop low-density, high-strength ordered intermetallic alloys for high-temperature structural use in advanced heat engines, energy conversion systems, and other industrial systems. Current efforts are focused on: (1) increasing the tensile ductility of NiAl and improving impact resistance of these alloys by control of microstructure and alloy composition, (2) increasing the tensile ductility and fracture resistance of TiAl-base alloys by control of grain size and lamellar structure, and (3) characterizing the oxidation and corrosion resistance of intermetallic alloys for industrial applications.

Keywords: Intermetallics, Ordered Alloys, Shape Memory Alloys

26. **RAPID SOLIDIFICATION PROCESSING OF METAL ALLOYS**
 $192,000
 DOE Contact: Charles A. Sorrell, (202) 586-1514
 Idaho National Engineering Laboratory Contact: J. E. Flinn, (208) 526-8127

The industrial sector requires metallic alloys whose properties, performance, and reliability extend beyond those obtained from current processing practices. These needs can be fulfilled by metallic alloys that have fine and stable (to high temperatures) microstructures. Rapid solidification processing (RSP) by design can fulfill these need through control of alloy chemistry and powder processing parameters. Significant improvements have been observed for RSP 304 SS, A286, and 718 alloys compared to their ingot metallurgy counterparts. A nickel-base alloy has been designed for the RSP approach using the knowledge from the research findings and input from the industrial sector. In addition, four Cooperative Research and Development Agreements (CRADAs) have been signed to compare the microstructure, properties and performance limits of selected alloys/materials currently being used with those obtained by RSP. These materials are for high temperature electrical, corrosion and wear, and photovoltaic applications.

Keywords: Rapid Solidification, Alloys, High Temperature Microstructure

27. **PROCESSING OF POLYMERS IN A MAGNETIC FIELD**
 $316,000
 DOE Contact: Charles A. Sorrell, (202) 586-1514
 Los Alamos National Laboratory Contacts: Elliot P. Douglas, 505 665-4828

The purpose of this project is to demonstrate the utility of magnetic fields to beneficially modify or control the physical, optical and electrical properties of materials through the application of magnetic fields during polymerization processing and solidification. Researchers at Los Alamos National Laboratory, in collaboration with an industrial partner, have demonstrated that using high (10-20 Tesla) magnetic fields to orient liquid crystal polymers during processing can lead to substantial improvements in mechanical properties. Working at the National High Magnetic Field Laboratory, liquid crystal polymers were processed using a specially designed high temperature probe built for the 20 Tesla superconducting magnet. The probe insulates the liquid helium bath of the superconducting magnet from the high temperatures used in the processing, and results in a thermal gradient of more than 400 °C over a distance of approximately 2.5 cm. The tensile modulus, in the magnetic field alignment direction, of a polymer processed in a 15 Tesla magnetic field was double that of the same material processed with no magnetic field present. Current work is focusing on understanding the mechanisms of the orientation process and the relationship among field strength, time in the field, and properties.

Keywords: Organic Polymers, Magnetic Processing, Mechanical Properties

28. **MICROWAVE JOINING OF SiC**
$205,000
DOE Contact: Charles A. Sorrell, (202) 586-1514
LANL Contact: Joel D. Katz, (505) 665-1424
FM Technologies, Inc. Contact: R. Silberglitt, (703) 425-5111
George Mason University Contact: W. Murray Black, (703) 993-4069

The objective of this project is to develop and optimize a joining method that can be applied to large scale fabrication of components such as radiant burner tubes and high temperature, high pressure heat exchangers. Microwave joining of both reaction bonded silicon carbide and sintered silicon carbide has been demonstrated for tubes up to 5 cm in diameter. Joints are leak tight at service temperature, and have adequate mechanical strength for desired applications. Work is continuing to scale-up tube joining further (up to 11.4 cm diameter) and to develop a joining method using preceramic polymers. Collaborative work with an industrial partner has been initiated to demonstrate scale-up of the joining technique on a radiant burner tube assembly application in the steel industry.

Keywords: Microwave Processing, Microwave Joining, SiC

DEVICE OR COMPONENT FABRICATION, BEHAVIOR OR TESTING

29. **Ni_3Al TECHNOLOGY TRANSFER - STEEL MILL ROLLS AND FURNACE FIXTURES**
$1,050,000
DOE Contact: Charles A. Sorrell, (202) 586-1514
ORNL Contacts: M. L. Santella, (615) 574-4805 and V. K. Sikka, (615) 574-5112

The objective of this project is to apply the excellent oxidation and carburization resistance and higher strength of nickel aluminides to Industries of the Future related manufacturing applications. Progress in bringing technologies to development and commercialization in FY 1995 included: (1) Development of a new process known as *Exo-Melt* for the commercial melting of nickel aluminide alloys (winner of an R&D 100 Award in 1995); (2) In-service testing of nickel aluminide rolls for steel mill reheat furnaces for over a year. Alloy and welding methods were developed by Oak Ridge National Laboratory; alloys were produced by Metallamics, Inc., rolls were cast by Sandusky International, and rolls continue to be tested by Bethlehem Steel; (3) Long-term, in-service testing of nickel aluminide tray and fixtures for industrial carburizing furnaces. Alloy and casting methods were developed by Oak Ridge National Laboratory, casting was done by Alloy Engineering and Casting Co., and testing is being performed by General Motors Saginaw Division.

Keywords: Nickel Aluminides, Processing, Melting, In-Service Testing

30. **ADVANCED MICROWAVE PROCESSING CONCEPTS**
$250,000
DOE Contact: Charles A. Sorrell, (202) 586-1514
ORNL Contacts: R. J. Lauf and H. D. Kimrey, (615) 574-5176

The purpose of this project is to explore the feasibility of several advanced microwave processing concepts to develop new energy-efficient materials and processes as well as to reduce consumption of strategic metals. A variable frequency microwave furnace was developed by Oak Ridge National Laboratory and commercialized by Lambda Technologies. Current emphasis is on determining the curing behavior of thermosetting resins and polymer-matrix composites under microwave heating conditions. The cure time, physical properties, and uniformity of neat resins and prepreg layups as a function of microwave heating conditions such as average frequency, bandwidth, and power are being investigated.

Keywords: Microwave Processing, Polymers, Composites, Variable Frequency

31. **SELECTIVE INORGANIC THIN FILMS**
$400,000
DOE Contact: Charles A. Sorrell, (202) 586-1514
Sandia National Laboratories Contact: Mark Phillips, (505) 844-8969

The purpose of this research is to develop a new class of inorganic membranes for light gas separation and use this technology to improve on separation efficiencies currently available with polymer membranes, particularly for light alkanes. The approach is to nucleate and crystallize zeothlitic phases from sol-gel derived amorphous coatings, using porous filters and gas membranes as supports for these films. Current efforts have focused on controlling porosity in several oxide film compositions. These films have been deposited on quartz acoustic plate mode devices. Zeolite films and composite films of zeolites embedded in amorphous matrices have also been synthesized. Future efforts include utilizing nonalumino-silicate molecular sieves as membranes as well as exploring other sources of nutrient for zeolitic film crystallization.

Keywords: Coatings, Sol-Gel Processing

32. **CHEMICAL VAPOR INFILTRATION OF TiB_2 COMPOSITES**
$100,000
DOE Contact: Charles A. Sorrell, (202) 586-1514
Oak Ridge National Laboratory Contact: T. Besmann, (615) 574-6852

This program is designed to develop a Hall-Heroult aluminum smelting cathode with substantially improved properties. The carbon cathodes in current use require significant anode-to-cathode spacing in order to prevent shorting, causing significant electrode inefficiencies. A fiber reinforced-TiB_2 matrix composite would have the requisite wettability, strength, strain-to-failure, cost, and lifetime to solve this problem. The approach is to fabricate a cathode material through chemical vapor infiltration (CVI). Large-scale specimens (8 in^2 plates) for testing by the Alcoa Technical Center in bench-scale Hall-Heroult cells were prepared, at substantially reduced processing times, utilizing a forced chemical vapor infiltration (FCVI) system with a modified reactant feed system.

Keywords: Chemical Vapor Infiltration, Composites, Hall-Heroult Cell

ADVANCED TURBINE SYSTEMS PROGRAM

DEVICE OR COMPONENT FABRICATION, BEHAVIOR OR TESTING

33. **CERAMIC COMPONENTS FOR STATIONARY GAS TURBINES IN COGENERATION SERVICE**
$6,500,000
DOE Contact: S. Blazewicz, (202) 586-4679
Solar Contact: M. Van Roode, (619) 544-5549

The performance of stationary gas turbines is limited by the temperature and strength capabilities of the metallic structural materials in the engine hot section. Because of their superior high temperature strength and durability uncooled ceramics can be used in the engine hot section at increased turbine inlet temperatures. An existing gas turbine engine will be retrofitted with first stage ceramic blades, first stage ceramic nozzles and ceramic combustor liners. This project will design and test these components for a stationary 3.5MW gas turbine for cogeneration service. The three components are the combustor, first stage rotor, and first stage nozzle. The project will culminate in a 4000 hour field demonstration of the engine.

Keywords: Structural Ceramics, Cogeneration, Gas Turbines

34. **LONG-TERM TESTING OF CERAMIC COMPONENTS FOR STATIONARY GAS TURBINES**
$500,000
DOE Contact: S. Blazewicz, (202) 586-4679
ORNL Contact: M. Ferber, (615) 576-0818

The service life requirements for a land-based Advanced Turbine System (ATS) are significantly longer than for aircraft turbines and will impact the objectives of the respective materials development programs. Land-based gas turbines are generally required to operate for longer periods under steady-state conditions, and creep damage becomes the major consideration. This program performs the characterization tasks of the ATS materials/manufacturing program. This project will test monolithic ceramics in static and cyclic fatigue for up to 10,000 hours at gas turbine utilization temperatures.

Keywords: Structural Ceramics, Cogeneration, Gas Turbines

35. **ATS MATERIALS BASE TECHNOLOGY SUPPORT**
$4,000,000
DOE Contact: S. Blazewicz, (202) 586-4679
ORNL Contact: M. Karnitz, (615) 576-5150

Gas turbine manufacturers have stated a need for a turbine inlet temperature of greater than 2600°F in order to achieve higher efficiencies. New materials developments are necessary to achieve these temperatures for extended operating periods. Advanced casting techniques, metallurgy and coating science will be applied to gas turbines to allow higher operating temperature for increased efficiency while producing fewer emissions. The goals of these projects are improved turbine airfoil castings and reliable, higher performance thermal barrier coatings that will allow for increased turbine inlet temperature.

Keywords: Gas Turbines, Castings, Thermal Barrier Coatings

HEAT EXCHANGER PROGRAM

MATERIALS PROPERTIES, BEHAVIOR, CHARACTERIZATION OR TESTING

36. **ADVANCED HEAT EXCHANGER MATERIAL TECHNOLOGY DEVELOPMENT**
$617,000
DOE Contact: G. Varga, (202) 586-0082
ORNL Contact: M. Karnitz, (423) 574-5150

This project conducts research to evaluate advanced ceramic materials, fabrication processes and joining techniques. The effects of hot, corrosive environments on candidate ceramic and ceramic composite materials continue to be investigated. Also under investigation is the performance of advanced ceramic materials subjected to the processing environments encountered in steam cracking for ethylene production and steam reforming for synthesis gas production.

Keywords: Structural Ceramics, Corrosion-Gaseous, Industrial Waste Heat Recovery

DEVICE OR COMPONENT FABRICATION, BEHAVIOR OR TESTING

37. **CERAMIC COMPOSITE HEAT EXCHANGER FOR THE CHEMICAL INDUSTRY**
$138,801
DOE Contact: G. Varga, (202) 586-0082
Babcock & Wilcox Contact: D. Hindman, (804) 522-5825

The performance evaluation of an advanced ceramic composite heat exchanger in the high temperature, corrosive environment of a hazardous waste incinerator has been completed. Evaluation of the materials involved has been completed and a final report is in preparation.

Keywords: Ceramic Composites, Structure

38. **HiPHES SYSTEM FOR ENERGY PRODUCTION**
$316,676
DOE Contact: G. Varga, (202) 586-0082
Solar Turbines Contact: B. Harkins, (619) 544-5398

This project is in the second phase of a three-phase effort to develop high pressure heat exchange systems (HiPHES) for recovery of energy from the combustion of hazardous wastes. A multi-tube proof-of-concept test is underway and high temperature exposure testing to the hazardous waste incinerator environment is continuing.

Keywords: Ceramic Composites, Heat Exchangers

39. **HiPHES SYSTEM FOR ETHYLENE PRODUCTION**
$1,036,000
DOE Contact: G. Varga, (202) 586-0082
Stone & Webster Engineering Corp. Contact: J. Gondolfe, (713) 368-4379

This project has been reoriented. The new target is a steam cracker for ethylene production, a more attainable goal with a more wide-spread applicability than the steam reformer planned previously. Research on critical material needs continues taking full advantage of previous data which will apply to the new goal.

Keywords: Composites, Heat Exchangers

CONTINUOUS FIBER CERAMIC COMPOSITES (CFCC) PROGRAM

MATERIALS PREPARATION, SYNTHESIS, DEPOSITION, GROWTH OR FORMING

40. **CFCC PROGRAM - INDUSTRY TASKS**
    $5,977,000
    DOE Contact: M. Smith, (202) 586-3646

The goal of the CFCC Program is to develop, in U.S. industry, the primary processing methods for the reliable and cost-effective fabrication of continuous fiber ceramic composite components for use in industrial applications. The first phase, completed in 1994, established performance requirements of applications and assessed feasibility of potential processing systems. Phase two, process engineering and component development, is in progress.

Keywords: Ceramic Composites, Continuous Fiber

MATERIALS PROPERTIES, BEHAVIOR, CHARACTERIZATION OR TESTING

41. **CONTINUOUS FIBER CERAMIC COMPOSITES (CFCC) SUPPORTING TECHNOLOGIES**
    $2,300,000
    DOE Contact: M. Smith (202) 586-3646
    ORNL Contact: M. Karnitz, (423) 574-5150

This project provides basic or generic support to the industry teams conducting CFCC research. Tasks include: composite design, materials characterization, test methods development, database generation, codes and standards, and life prediction.

Keywords: Ceramic Composites, Fiber Architecture, Material Characterization, Test Methods